Claims

What is claimed is:

1. A method for analyzing a circuit network, comprising:

representing a circuit network by using a matrix of nodes having fine nodes and coarse nodes;

applying an adaptive coarse grid construction procedure to assign grid nodes in the matrix as either coarse grid nodes or fine grid nodes according to (1) circuit activities and (2) a matrix structure of the matrix to construct a plurality of levels of grids with different numbers of nodes to respectively represent the circuit network; and

applying iterative smoothing operations at selected local fine grids corresponding to active regions at a finest level obtained in the adaptive coarse grid construction procedure.

2. The method as in 1, wherein the coarse grid nodes are divided into non-adaptive coarse nodes which are selected according to the matrix structure, and adaptive coarse nodes which are selected according to circuit activities.

3. The method as in claim 2, wherein, in assigning non-adaptive coarse nodes, a node with a maximum potential in its degree is selected as a first non-adaptive coarse node and each neighboring node of the first non-adaptive coarse node is temporality assigned as a fine node, and wherein a potential

of each neighboring node of the first non-adaptive coarse node is increased by one unit before a next level of assigning coarse and fine grid nodes so that each fine node has at least one neighboring coarse node upon completion of assigning non-adaptive coarse nodes.

4. The method as in claim 2, wherein an adaptive coarse node is selected according to a first-order derivative of a nodal voltage.

5. The method as in claim 4, wherein a coarse node is selected as an adaptive coarse node when the first-order derivative the coarse node is greater than a threshold value.

6. The method as in claim 5, further comprising selecting adaptive coarse nodes in a level that is not the finest level.

7. The method as in claim 1, after the iterative smoothing operations in a level, further comprising:

applying a restriction mapping of nodes in the level to a next level with less nodes;

performing iterative smoothing operations again at the next level; and

repeating the restriction mapping and the iterative smoothing operations until reaching a level of nodes which are

solvable by a direct matrix solving method such as a Gaussian elimination method.

8. The method as in claim 1, after the iterative smoothing operations in a level, further comprising:

applying an interpolation mapping of nodes in the level to a next level with more nodes;

performing iterative smoothing operations again at the next level; and

repeating the interpolation mapping and the iterative smoothing operations until reaching the finest level of nodes.

9. The method as in claim 8, further comprising:

computing a residual value of an error after the iterative smoothing operations at the finest level;

comparing the residual value to a pre-determined threshold;

terminating any further processing when the residual value is less than the threshold; and

when residual value is greater than the threshold, the method further comprising:

applying a restriction mapping of nodes in the finest level to a next coarser level with less nodes,

performing iterative smoothing operations again at the next coarser level; and

repeating the restriction mapping and the iterative smoothing operations until reaching a coarsest level of nodes which is solvable by a direct matrix solving method such as a Gaussian elimination method,

applying an interpolation mapping of nodes in the coarsest level to a next finer level with more nodes,

performing iterative smoothing operations at the next finer level,

repeating the interpolation mapping and the iterative smoothing operations until reaching the finest level of nodes, and

repeating the restriction mapping, the interpolation mapping and the respective iterative smoothing operation at different levels until the residual value at the finest level is less than the threshold.

10. The method as in claim 1, further comprising dynamically changing designations of active and inactive regions of the circuit network according to circuit activities at different times.

11. The method as in claim 10, further comprising applying iterative smoothing operations in active regions more frequently in time than in inactive regions.

12. The method as in claim 1, further comprising: in a passive linear circuit, applying different models to passive circuits exhibiting resistance and capacitance without inductance and passive circuits exhibiting inductance.

13. The method as in claim 12, further comprising separating nodal voltages and branch currents into different vectors during processing to make a system matrix to be symmetric and positive definite.

14. A method for analyzing a circuit network, comprising:

representing a circuit network by using a plurality of levels of grids with different numbers of nodes to represent the circuit network according to an algebraic multigrid method;

applying a restriction mapping from one level to a next coarser level to propagate computation results of the one level to the next coarse level;

applying an interpolation mapping from one level to a next finer level to propagate computation results of the one level to the next finer level;

performing an iterative smoothing operation at each level to obtain computation results of each level comprising states of nodes in each level; and

repeating (1) the restriction mapping and the iterative smoothing operation from the finest level to the coarsest

level and (2) the interpolation mapping and the iterative smoothing operation from coarsest level back to the finest level for at least one time to obtain a solution to the circuit network.

15. The method as in claim 14, wherein the coarsest level is a level where a matrix equation for nodes in the level is solvable by a direct matrix method such as the Gaussian elimination method.

16. The method as in claim 14, wherein at least one level includes nodes corresponding to only selected circuit regions in the circuit network that are active and does not include nodes corresponding to inactive circuit regions in the circuit network.

17. The method as in claim 14, further comprising:

assigning regions in the finest level with nodes corresponding to active circuit regions in the circuit network as active local fine grids; and

performing the iterative smoothing operation only in the active local fine grids in the finest level to obtain computation results of the finest level.

18. The method as in claim 14, further comprising:

assigning regions in a level with nodes corresponding to active circuit regions in the circuit network as active local grids and other regions in that level as in inactive grids; and

performing the interactive smoothing operation in an active local grid more frequently than in an inactive grid.

19. The method as in claim 14, further comprising applying an adaptive coarse grid construction procedure to assign grid nodes in the matrix as either coarse grid nodes or fine grid nodes.

20. The method as in claim 19, wherein a coarse node is assigned by:

assigning a node with a maximum potential to its degree as a first coarse node and all neighboring nodes as initial fine nodes;

for each of the initial fine nodes, increasing a potential of each of neighboring nodes by one unit;

assigning a node which has a maximum potential among other nodes except for the first coarse node as a second coarse node; and

repeating the assigning for nodes that are not assigned as coarse nodes until all nodes are assigned.

21. The method as in claim 19, wherein the coarse nodes are selected according to their values of a first-order derivative of a nodal voltage.

22. A method for analyzing a circuit network, comprising:

applying an algebraic multigrid method to a matrix representative of a circuit network to construct a plurality of matrices with different degrees of coarsening grids;

representing regions in the circuit network exhibiting active circuit activities with active grids and regions in the circuit network exhibiting less active circuit activities with inactive grids; and

performing an iterative smoothing operation in an active grid more frequently than in an inactive grid to reduce an amount of computation.

23. The method as in claim 22, further comprising:

applying a restriction mapping of nodes in a coarse grid to a next coarser grid;

performing the iterative smoothing operation at the next coarser grid; and

repeating the restriction mapping and the iterative smoothing operation until reaching the coarsest grid which has a matrix equation that is solvable by a direct matrix solving method such as a Gaussian elimination method.

23. The method as in claim 22, further comprising:

applying an interpolation mapping of nodes in one grid to a next finer grid;

performing the iterative smoothing operation at the next finer level; and

repeating the interpolation mapping and the iterative smoothing operation until reaching the finest grid.

25. An article comprising a machine-readable medium that stores machine-executable instructions, the instructions causing a machine to:

apply an algebraic multigrid method to a matrix representative of a circuit network to construct a plurality of matrices with different degrees of coarsening grids;

divide the circuit network into active regions and inactive regions according to circuit activities; and

perform an iterative smoothing operation in an active region more frequently than in an inactive region.

26. The article as in claim 25, wherein the machine-executable instructions further comprise instructions that cause the machine to perform an iterative smoothing operation to solve for a matrix equation of each grid and to map a computation result of each grid to a next finer or coarser grid until a residual error of a solution is less than a pre-determined threshold.